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ABSTRACT

To integrate findings concerning the influence of productive factors on student achievement and attitudes across various disciplines and ages, nine regression studies of National Assessment of Educational Progress samples containing a total of 15,802 students were quantitatively synthesized. Correlations and standardized regression weights for achievement and attitude and nine productive factors were compiled for four subjects--math, science, social studies and reading,--and two age groups--13- and 17-year olds. The effects of student socioeconomic status (a proxy for ability) and motivation; amount and quality of instruction; school, home, and peer-group environments; and exposure to television, when controlled for one another and for race and gender, are generally significant and consistent across subjects and ages for achievement and attitude outcomes. The over-all signs and apparent influences of each factor were positive except for television viewing which was negatively associated with achievement and attitude. (Author/PN)

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Productive Factors in School Learning:
A Quantitative Synthesis of National Assessment Studies

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Abstract

To integrate findings concerning the influence of productive factors on student achievement and attitudes across various disciplines and ages, nine regression studies of National Assessment samples containing a total of 15,802 students were quantitatively synthesized. Correlations and standardized regression weights for achievement and attitude and nine productive factors were compiled for four subjects--math, science, social studies and reading,--and two age groups--13- and 17- year olds. The effects of student socioeconomic status (a proxy for ability) and motivation; amount and quality of instruction; school, home, and peer-group environments; and exposure to television, when controlled for one another and for race and gender, are generally significant and consistent across subjects and age for achievement and attitude outcomes. The over-all signs and apparent influences of each factor were positive except for television viewing which was negatively associated with achievement and attitude.

Productive Factors in School Learning:
A Quantitative Synthesis of National Assessment Studies

The purpose of this paper is to synthesize quantitatively the results of National Assessment of Educational Progress (NAEP) studies that have regressed achievement and attitudinal learning-outcome measures on nine hypothesized productive factors in school learning (Walberg, 1981). Prior theory and extensive syntheses of intensive small-scale correlational, quasi-experimental, and experimental--research suggest that academic learning is consistently correlated and possibly caused by nine proximal, intra- and extra-mural factors: student age (or development), ability, and motivation and quality of instruction (including self-instruction); the social-psychological environments of the class (or school), home, and peer group outside school; and exposure to mass media, particularly television (Walberg, 1981, 1983b).

Few of the prior intensive studies, however, are national in scope; and most analyze only one or two factors and only sample limited populations within a school or community. They are often strong on observational technique, measurement, verification, and random assignment to treatments--in short, internal validity, but they are often weak in generalizability or external validity since they do not rigorously sample from large well-defined populations.

Survey research has complementary strengths and weaknesses: it often draws large stratified, random samples of national populations and measures many variables but sacrifices internal validity since the variables are meas-

ured most often cross-sectionally and perhaps superficially with only a few items without direct verification. Survey research, nonetheless, can statistically control for multiple causes simultaneously and in this respect can be stronger in internal validity than quasi-experiments that are only controlled for one or two covariates.

Such multivariate analyses of survey data are also potentially more efficient than small-scale, intensive quasi-experiments in that a greater number of variables may be simultaneously investigated, a broader range of groups may be studied, and the results may be generalized to significant large populations sampled. The complementarity of intensive and extensive studies, however, is important. In principle, powerful, worthwhile effects should consistently emerge from either form of research. Robust findings give a more solid basis for educational policy and practice. Since approximately 70 syntheses of a few thousand intensive studies support the positive effects or correlations of the nine productivity factors or their more specific aspects (Walberg, 1983b), it is the purpose of the present study to investigate the stability of correlations and standardized regression weights (that control the factors for one another) across the ages and subjects represented in the National Assessment of Educational Progress. (The youngest samples--nine-year olds are omitted from the research and from the present synthesis because the factors are mostly unrepresented in the data for this age group.)

Method

Sample of Studies

Nine papers analyzing the influences of the productive factors on the achievement and learning attitude of 13- and 17- year olds were selected for synthesis (see Appendix for references). These papers constitute the complete set of regressions of National Assessment of Educational Progress (NAEP) data known to the authors, although many studies appear to be in process since public-use data tapes have recently become available at low cost from the Educational Commission of the States in Denver and the Institute for Social and Political Research of the University of Michigan.

Each of the papers used in this study was an analysis of NAEP data collected between 1976 and 1978. NAEP uses a stratified, multi-stage sampling design that provides a basis for making statistical inferences to nearly the complete national population of children at various ages. Table 1 shows that the samples for the nine studies range from 2,001 to 3,680 students with a median of 2,386 and a total of 15,802.

(insert Table 1 about here)

Variable Definitions and Reliabilities

Because NAEP's major purpose is to estimate changes in item achievement in national samples over time, it is understandable that fewer items and student time are allocated for measuring other constructs. For instance, not all productive factors are represented on each data set (note the blank spaces in Table 1). In some samples, they are measured by only a few items and with

lower internal consistency reliability. However, the generally high reliabilities of the achievement measures, the rigorous sampling procedure and the representation of four or more of the factors in each data set makes the analysis worthwhile. In addition, results that emerge notwithstanding measurement problems under-estimate the true relationships and thus provide conservative estimates.

Operational definitions of the variables are shown in Table 1. Quality of instruction was measured by anywhere from two to seventeen items regarding direct didactic or student-centered instruction. Stimulation was determined by three or four items regarding the frequency of course-related activities. The quantity of instruction was determined by the number of courses taken or the amount of time spent in classes in each of the disciplines. From two to seven items were used to assess it.

School or class morale was determined by from four to twenty one items. Home characteristics were assessed on a basis of between four and twelve questions regarding home characteristics. Amount of homework was based on hours spent doing homework the night before (or in one case, the previous week) and amount of time spent watching television the evening previous to responding to the questionaire and achievement tests.

The number of items used to assess achievement varied from 15 to 60 with a median of 46. Attitude was determined by anywhere from one to twenty-seven questions regarding frequency of subject-related activities when not required of students (the median is eight.)

Achievement had high alpha internal consistency reliabilities ranging from .78 to .92 with an average of .84. The reliability of the attitude measures

was also high (average of .78) with the exception of the reliability coefficient of .47 for math attitude. The reliability of class morale and quality of instruction for the science studies was also high (.80 and .78 respectively) but was lower in the other subjects (.48 and .57). The mean alpha reliability coefficient for quantity of instruction was .66.

(Insert Table 2 about here)

Analysis

Stem-and-leaf diagrams (Tukey, 1977) were constructed to reveal the location, spread, and shape of the distribution of correlations and standardized regression weights to detect outlying, possibly aberrant data points. Four-way analyses of variance testing the effects of subject, age, type of learning, and productivity factor were computed for both the correlations of the factors with achievement and attitude as well as the super-standardized weights as dependent variables.

One of the nine studies (Welch, Anderson, & Harris, 1982) reported no regression weights. Of the other eight studies, two reported separately on achievement and attitudinal learning even though they used the same data set. These two studies were each weighted by a factor of .5 in the analysis so that each data set would have an equal weight of one (SAS Institute, 1982. p. 156).

To depict the influences of the significant factors on the magnitude of the correlations and weights, schematic plots (also called box or box-and-whisker charts) were drawn by computer. These show the extremes, 25th and 75th percentiles, and median and mean of the data points for combinations of dependent variable and classification, in this case, the correlations and significant factors in the analysis of variance (Tukey, 1977).

Results

Tables 1 through 4 and Figures 1 through 3 summarize the results of the analysis. Univariate statistics and distributions are first presented, then results of the analysis of variance, and finally the schematic plots for the significant variables. The correlations are discussed first and then the super-standardized weights.

Correlations

Table 3 shows a stem and leaf diagram of the correlations. The digits in the left column show the tenths of each correlation and the numbers on the right show the hundredths. For example, the highest correlation, .68, is indicated by an .08 leaf on the .6 stem.

Table 3 shows that the correlations are slightly negatively skewed and range from -.45 to +.68 with a mean and a median of .19. Thus an increase in achievement and attitude outcome of about .2 is, on the average, associated with an increase of one standard deviation, say, from the 50th to the 84th percentile, in any productivity factor uncontrolled for the other factors. The t-test of the mean correlation given the hypothesis of zero is 11.34 which is significant at the .0001 level.

As shown in the table, however, several correlations are outliers. For example, the .68 correlation of math achievement for 17-year olds with quantity of instruction and the correlation of social studies attitudes of 13-year olds with achievement are aberrantly high (see also Table 1). The low negative outlying correlation of -.45 represents the association of science attitudes of 13-year olds with the quality of instruction.

(Insert Table 3 about here)

In the four-way analysis of variance of the correlations, the F-tests showed that subject, learning, and productivity factors were statistically significant at the .05 level. Age was not significant (see Table 4).

(Insert Table 4 about here)

The schematic plots for the correlation of significant variables are shown in Figures 1 through 3. Figure 1 shows the schematic plots of the correlations for the productivity factors and other independent variables reported in the studies. The highest mean correlation is for home environment and the lowest are with female and television-viewing. Amount of television viewing correlates negatively with learning as expected but its correlations were coded as positive in the statistical analyses so as not to distort the magnitude of the over-all correlations and arbitrarily reduce the scale of the stem-and-leaf diagrams and box plots.

(Insert Figures 1 - 3 about here)

Figure 2 shows the box plots of correlations by subjects. The robustness of the correlations is illustrated here, too, as the means are all very close to .20 with social studies being somewhat higher which makes subject significant in the analysis of variance.

The correlations for achievement and attitude are shown in Figure 3. The correlation with achievement as the dependent variable tends to be slightly higher than those for attitude; but both are just below .20 on the average.

Standardized Weights

The standardized weights are shown in Table 2. The two stem-and-leaf diagrams in Table 3, show that the correlation values are somewhat higher than the weights. Also the weights are more skewed than the correlations and in a positive direction. The mean weight is .11, and the t-test of the mean weight given the hypothesis of zero is 7.38, which is significant at the .0001 alpha level. Thus, controlled for the other factors, an increase in any factor is associated with a typical increase in learning of only .11.

The analysis of variance of the standardized weights showed none of the factors to be significant at the .05 level. Thus the factors do not differ from one another in magnitude or overall relation to learning outcomes. The weights for attitude and achievement are not significantly different when controlled for one another, and the analysis indicates there are no statistically significant differences in weights attributable to subject matter or age.

Conclusion

The results of the analysis of the nine NAEP samples containing 15,802 students show that the typical correlation of achievement and attitude with the nine productivity factors is .19. The middle 50 percent of the correlations range from about .10 to .30; and the extreme and possibly aberrant correlations range from -.45 to +.68. The magnitudes of the correlations depend slightly but significantly on the type of learning outcome (achievement or attitude), subject matter, and productivity factor.

When controlled for one another and for sex and ethnicity, however, the average standardized regression weight of the factors is .11, and none of the categories within classifications of subject matter, age, type of learning, or productivity factor were significantly different from the others. To unknown extents, the estimates of the correlations and weights are both upwardly and downwardly biased. They may overestimate the true weight because only subsets of the nine productivity factors were included in the test packages and therefore in the analyses (see Table 2). They are underestimated because of the attenuation attributable to less than perfect validity of measurement of learning and the factors, the lack of teaching and curricular validity of the tests in measuring what is taught to particular classes and students, and the narrow range of measurement of the factors.

If the factors cause one another as well as directly cause learning (see Walberg, 1981, for alternative causal models), the correlations and weights are still more underestimated. Nonetheless, because of the consistency of the findings, their agreement in sign with syntheses of quasi-experimental studies, the multivariate analyses and statistical controls of multiple factors, and the national sampling, the results have at least three sets of research and practical implications.

First, the reduction from about .2 for the average correlation to about .11 for the average statistically-controlled weight implies large colinearities among the productivity factors. Indeed, examination of the correlation matrices in the original articles shows many moderate correlations among the factors from .4 to .6 and a few as high as .8. The colinearity is no doubt attributable in part to response biases of some students perceiving or rating

most factors favorably and other students rating them unfavorably whatever the veridical or objective levels of the factors.

In addition, however, "Matthew effects" (Walberg & Tsai, 1983) abound in education; those advantaged on one factor such as home environment are likely to be advantaged on other factors such as ability, motivation, environment, and instruction. Such colinear advantages shown in the primary research and in the present synthesis may explain large variations in achievement, cummulative deficits, and the phenomenon of the educationally rich getting richer.

Second, the average weight suggests that, with the other factors held constant, a one standard-deviation (SD) increment in any factor, say, from the 50th to the 84th percentile, is associated with a .11 SD increment in learning, or, in the present example, from the 50th percentile in learning to the 54th--a trivial advantage. On the other hand, simultaneously raising all nine factors one SD is associated with an increment from the 50th to the 84th percentile of achievement or attitude (although the regressions do not contain all factors). To take a more extreme example, a rise of four SDs from the 2nd to the 98th percentiles on all the factors is associated with an increment of 96 percentile points from, say, the 2nd to the 98th percentiles of learning. These figures are underestimated to the extent that the measures of independent and dependent variables are unreliable and lack curricular validity, and are overestimated to the extent that not all factors are represented in all regressions.

These along with other estimates nonetheless suggest that policy makers and educators who are determined to raise achievement (especially in science and mathematics in which the evidence seems most clear and the need may be

greatest) should attempt to raise as many of the factors--including the extra-mural ones--as much as possible to raise learning to the levels of Japan, Europe, and other technologically-advanced countries (Walberg, 1983a). The results also support case studies and the general hypothesis that world-class performance in chess, ballet, swimming, debate, and other competitive fields as well as academic learning requires teachers, parents, and the competitors themselves to give their lives to optimizing all the factors simultaneously for about a decade (Simon, 1981; Walberg, 1983a). Because such sustained, cooperative and all-out effort is difficult, true excellence or one's best remains rare.

Third, the results support the theoretical view that no single factor dominates learning; any factor--most plausibly ability, motivation, and amount and quality of instruction--may be necessary but insufficient by itself for learning. The results, however, disconfirm the aspects of a theory of educational productivity that strongly infer that a linear, non-interactive equation is inadequate and that explicitly hold that the factors interact multiplicatively with diminishing returns (Walberg, 1981). On the contrary, several primary studies on which the present synthesis is based provide little evidence that logged Cobb-Douglas equations provide better fits than untransformed sets of variables.

These aspects of the theory, however, cannot be dismissed because both learning and the factors are measured over small ranges. The measures are hardly cardinal or ratio in the economic or psychological senses; they clearly vary but are hardly measured over several magnitudes in the way that physical inputs, dollars, and time are measured from zero to more than thousands of

equal units in studies of agricultural, biological, and industrial productivity. The only factor, moreover, that may be cardinal in measure--time--does in fact show diminishing learning returns in studies that have explored log transformations (Walberg, 1983b).

Carroll (1982) finds little fundamental progress in mental measurement since Thurstone in 1925; even the recent parsimonious and multiple-parameter item models seem to him minor elaborations of earlier insights or oversimplified assumptions for mathematical tractability of measures wrongly collected or construed (p. 67, 77). As he ironically notes, recently proposed and promising "tailored" testing in which tests are flexibly adapted to students over a great range of ability rather than vice versa is a reversion to Binet's turn-of-the-century precedent of suiting items to ability and calibrating mental age with a ratio variable--chronological age (p. 66). Before educational-productivity research can establish the magnitude and form rather than simply the sign of the dependence of learning on its factors and thereby more efficiently guide the optimization of learning, it may be necessary to develop adaptive, cardinal measures over several magnitudes of all factors in the equation.

Appendix

Papers Used in This Study

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Table 1

Definitions of Samples and Variables

Factor	Science 13	Science 17	Math 17	Social Studies 13	Social Studies 17	Reading 17
	N=2,346	N=3,049	N=3,680	N=2,426	N=2,001	N=2,300
Achievement	53 science achievement items	60 science achievement items	55 items in 5 content & 4 cognitive process areas	31 social science achievment items	38 items of student knowledge & understanding of social studies issues & ideas	15 items in reading/literature achievement
Attitude	8 items--science activities when not required	8 items - science activities	3 items on willingness to study math not assigned	17 attitude items toward social science	27 items of attitudes or beliefs about social studies & citizenship	1 item on enjoyment of reading
Socioeconomic Status	Highest amount of either parent's education.....					
Quality of Instruction	17 items direct didactic instruction	16 items direct didactic instruction	2 items on either traditional or student - centered instruction	5 items instructional methods using student participation	Either 2 items traditional instruction or 7 items on student centered instruction	
Quantity of Instruction			7 items indicating math courses taken; summed to give years of math studied	3 items - amount of classes to discuss politics or government	5 items - amount of class time spent studying government processes and issues	2 items - frequency of unrequired reading
Education (Class)	21 items on social/psychological morale of class	21 items on social/psychological morale of class			4 items - students' evaluation of effect on understanding & interest in political issues	

Table 1 (Continued)

Home	4 items-home characteristics	4 items-home characteristics	12 items-home characteristics	4 items-home characteristics	4 items-home characteristics	11 items-home characteristics
Peer	Primary parent occupation as determined by school principal	Primary parent occupation as determined by school principal				
Extra-Curricular					Degree of participation in extra-curricular activities	
Homework		Time spent yesterday on homework	Time spent yesterday on homework		Time spent per week on homework	Time spent on homework yesterday
Stimulation			4 items frequency of course related activities		3 items frequency of course related activities	
Media-Television			Time spent watching television last night		Time spent watching television last night	Time spent watching television last night

Table 2

Correlations of Achievement/Attitude with Productive Factors

Subject	Age	Achievement	Attitude	Socioeconomic Status	Quality of Instruction	Quantity of Instruction	Education (Class)	Home	Peer	Homework	Media-Television	Extra-Curricular	Stimulation	Locus
Science Achievement	13	1.00	.155	.19	-.085		.30	.355	.19					
Science Attitude	13	.155	1.00	.065	-.45		.45	.07	-.085					
Science Achievement	17	1.00	.255	.275	-.055		.285	.335	.245	.18				
Math Achievement	17	1.00	.04	.34	.245	.68**		.41		.21	-.19		.23	-.09
Math Attitude	17	.04	1.00	-.03	.135	.10		-.03		.18	-.02		.22	.06
Social Studies Achievement	13	1.00	.59	.33	.15	.17		.37						.02
Social Studies Attitude	13	.59	1.00	.25	.22	.17		.29						.11
Social Studies Achievement	17	1.00	.43	.35	.20	.27	.16	.37		.16	-.12	.16	.19	-.11
Social Studies Attitude	17	.43	1.00	.15	.23	.30	.26	.25		.24	-.05	.34	.26	.14
Reading Achievement	17	1.00	.19	.35		.16		.37		.17	-.08			.01
Reading Attitude	17	.19	1.00	.08		.30		.06		.18	-.03			.21
Indiana		.19	.222	.25	.15	.22	.285	.335	.19	.18	-.065	.25	.225	.04

* p≤.05
** p≤.01

Table 3

Standardized Regression Weights of
Achievement/Attitude on Productive Factors

Subject	Age	Achievement	Attitude	Socioeconomic Status	Quality of Instruction	Quantity of Instruction	Education (Class)	Home	Peer	Homework	Media-Television	Extra-Curricular	Stimulation	Female
Science Achievement	13		.0857*	.0922*	.0698		.2498**	.2268**	.0540*					
Science Attitude	13	.0909*		.0300	-.2661**		.2732**	.0262	-.0980*					
Science Achievement	17		.0881*	.1366**	.0746*		.2692**	.1842**	.1016**	.0921**				
Math Achievement	17		.0380**	.0536**	.1696**	.1443**		.1443**			-.0546**			-.0848
Math Attitude	17	.0490			.1320**			-.0940**		.1280**			.1720**	
Social Studies Achievement	13		.4629**	.1488**		.0721**		.1649**						.0900
Social Studies Attitude	13	.5089**			.1170**	.0559*		.0590*						-.1502
Social Studies Achievement	17		.3238**	.1851**	.1212**	.1201**		.1360**			-.0551**			
Social Studies Attitude	17	.3391**			.0850**	.0879**	.0902**	.0670**		.0741**		.2128**	.0551**	.1369
Reading Achievement	17		.0630**	.1370**		.0527**		.1251**						
Reading Attitude	17	.0522**				.2494**				.0503**				.1231
Medians		.0909	.0869	.1366	.1010	.0879	.2595	.1306	.0540	.0831	-.0548	.2128	.1136	.0900

* $p \leq .05$

** $p \leq .01$

Table 4

Stem and Leaf

Correlations

Stem	Leaf	#
6	8	1
5	99	2
5		
4	5	1
4	133	3
3	5556777	7
3	0003344	7
2	5556677899	10
2	01112233444	11
1	5556666677777888999999	21
1	0012344	7
0	5666788	7
0	122344	6
-0	33	2
-0	9885	4
-1	1	1
-1		
-2		
-2		
-3		
-3		
-4	5	1

Multiply stem.leaf by 10**-01
Mean = .194
Standard Deviation = .163
T: Mean=0 11.34 p(T) ≤ .0001

Standardized Weights

Stem	Leaf	#
5	1	1
4	6	1
4		
3		
3	24	2
2	5577	4
2	13	2
1	567789	6
1	0222233344444	14
0	5555556666677777899999999	26
0	334	3
-0		
-0	98	2
-1	0	1
-1	5	1
-2		
-2	7	1

Multiply stem.leaf by 10**-01
Mean = .112
Standard Deviation = .121
T: Mean=0 7.38 p(T) ≤ .0001

Table 5

Analysis of Variance for Correlations with Four Variables

Source	df	Sum of Squares	F	Probability
Subject	3	0.0943	3.11	0.0311
Age	1	0.0000	0.00	0.948
Learning	1	0.0688	6.80	0.0110
Factor	12	0.3945	3.25	0.001

Figure 1

Correlations by Factors

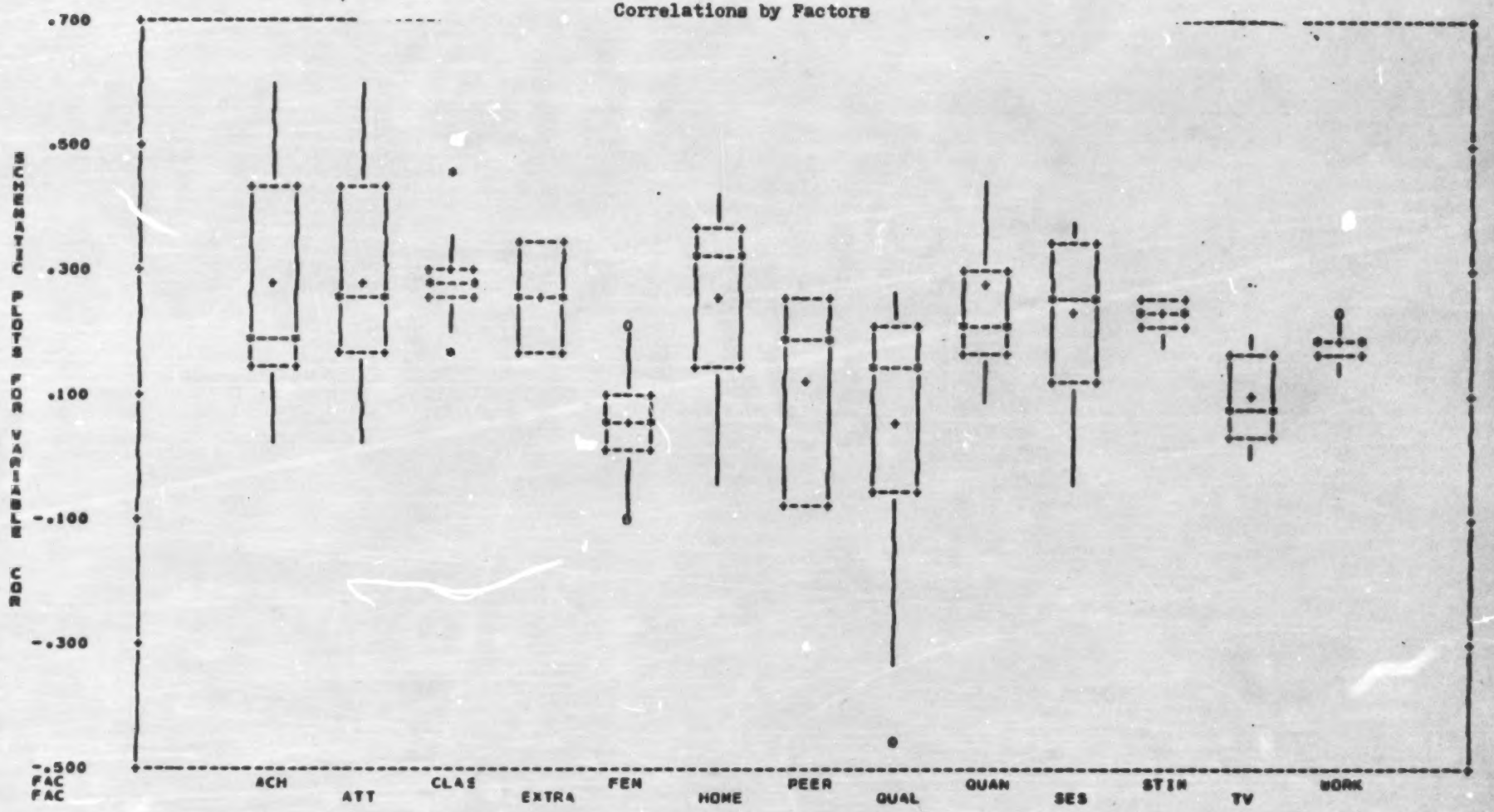

Figure 2

Correlations by Subjects

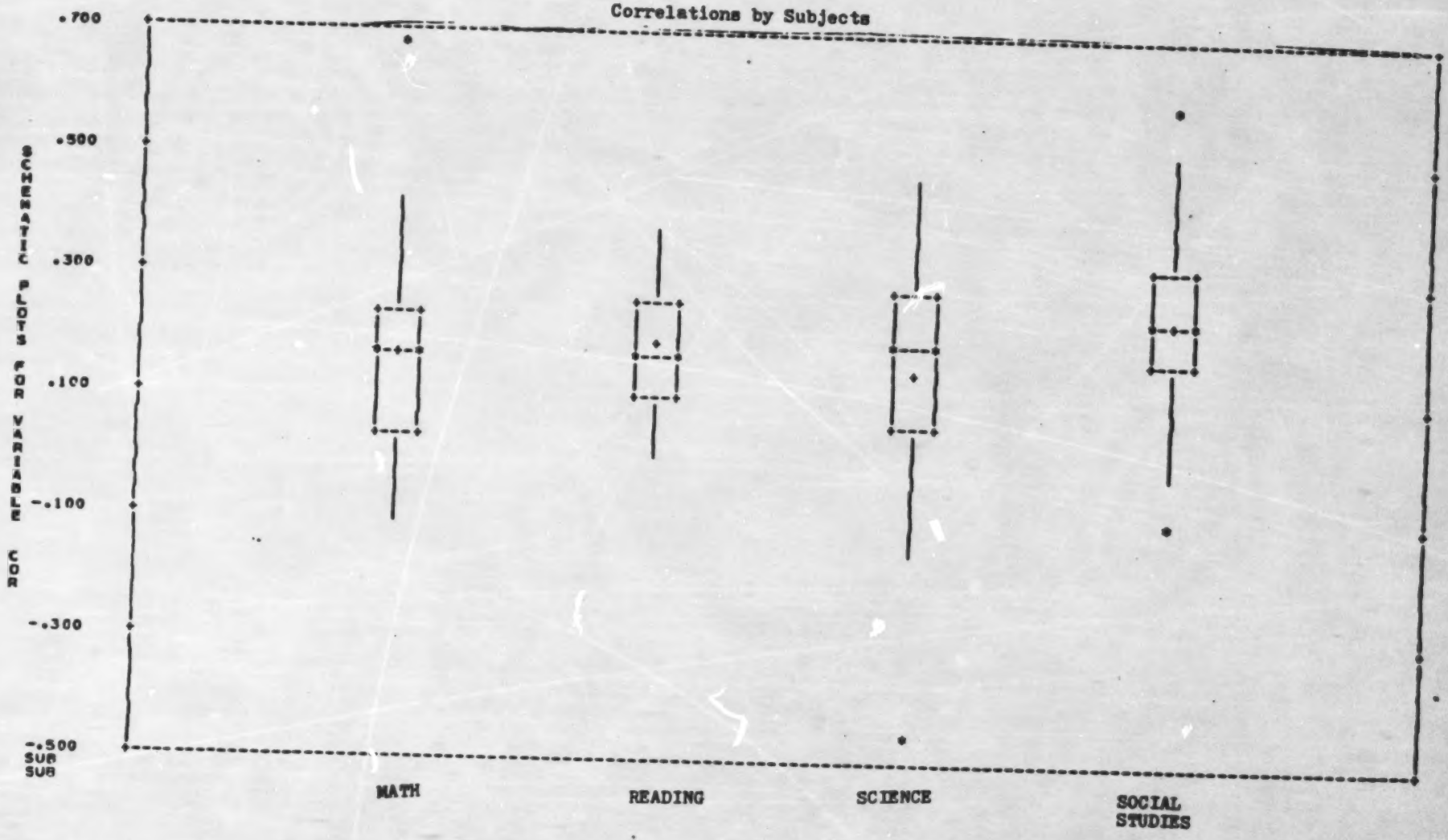

Figure 3

Correlations for Achievement and Attitude